

A fuzzy evaluation model: a case for intermodal terminals in Europe

RITA A. RIBEIRO^{*}, ANA M. D. MOREIRA^{*} AND EDDY DECLERCQ[#]

** Departamento Informática*

Faculdade Ciências Tecnologia, Universidade Nova Lisboa

2825 Monte da Caparica PORTUGAL

telephone: +351-1-294 85 36

fax: +351-1-294 85 41

e mail: rar@uninova.pt amm@di.fct.unl.pt

Strateco

Floris JaspersBuilding

1, Plantinkaai box 8

2000 Antwerp, BELGIUM

e mail: e.declerq@strateco.org

Abstract. Freight transport services have evolved substantially in the last decade and encountered a continuously increasing demand for speed, reliability, reduced transportation costs and value added services. To minimize the potential negative effects of the expected increase of commercial transport, the development of friendly transport concepts such as intermodal terminal selection is required.

The goal of our work is to develop a decision support system (DSS) for selecting the intermodal terminal that best fits required conditions and criteria. The DSS includes a simulation model developed using fuzzy logic techniques to handle imprecise concepts. The end-result is intended for decision-makers, i.e., managers that need to choose intermodal destination terminals to be used for the transportation of their goods.

1 Introduction

The objective of this work is to develop a decision support system to find the best terminals in a given country (and optionally in a given city)

which satisfy certain restrictions and criteria. In order to accomplish this, the following assumptions are made:

- distances between terminals are not handled;
- the origin terminal is not important, it is only important the destination terminal and conditions;
- intermediate terminals are not handled, since here we only consider the set of destination terminals;
- the model is developed both for passengers and cargo transport;

It should be noted that the information regarding the type of terminal required by the user also determines its intermodal combination. The types of modes the decision maker can select are, for example, road haulage, railway transport, inland waterway, maritime transport and airway transport. In this work we divided the terminals into passengers terminals and cargo terminals and they include as different modes: road, rail, sea, inland waterway and air. However, since we only deal with destination terminals we do not handle intermodal combinations.

Our system is a decision support system developed for non computer experts, using computer-assisted data input, processing wizards and other applications that facilitate its use. Our system lowers the threshold to use computer modeling in the strategic decision making process. It contains a multiplicity of data from different fields of interest. The information provides insights into the economic, social and infrastructure image of a country and is necessary at a level of strategic decisions.

The developed DSS contains the three classical modules of a DSS [Turban, 96]: database, simulation and interface. Its main features are:

1. It ranks the alternative destination terminals according to criteria values (cost, flexibility and reliability) and respective importances;
2. It is a flexible system for handling terminal features, such as modifications and new insertions;
3. It contains a sophisticated, but simple, algorithm for solving the rating and ranking of terminals, using a fuzzy multiple attribute model;
4. The fuzzy multiple attribute model includes fuzzy attributes (also denoted criteria) and fuzzy importances/weights and uses a weighted average aggregation procedure;
5. The construction of the fuzzy attribute membership functions is transparent to the user since the system extracts automatically the values from the database, to build them. This feature implies that

- with the increase of cases (terminals) in the database the attributes will better represent them;
6. It is interactive and user-friendly in all dialogue with the user. For example, it contains two levels for criteria importances to allow the user to detail criteria importances only when wanted;
 7. It incorporates a simulation facility, where the user can compare what are the results of changes in his/her criteria weights in the ranking of terminals.

The paper is structured in three sections. Section 1 is this introduction. Section 2 is the main body of this paper and it describes the three modules that compose our decision support system: the database module, the simulation module and the interface module. Section 3 presents the conclusions.

2 The decision support system

As mentioned, our DSS includes three modules:

- a conceptual data model and a data dictionary defining the structure of a relational database;
- the simulation module, which contains two main processes, (a) a pre-selection of terminals, according to the user specific needs and (b) a fuzzy multiattribute analysis to rank those terminals, according to the user preferences (weights);
- the interface to access the database and to establish the dialog with the user. The idea of wizards will be used to define the steps required to access the database.

The conceptual model of the database was obtained using structured analysis techniques [Yourdon, 89] and implemented using ACCESS. The simulation module uses fuzzy multiple attribute (criteria) concepts [Ribeiro, 96] [Zimmermann, 87]. The interface wizard will drive the user through the process of entering data necessary for defining the transportation framework requirements, the conditions, the criteria and the weights. The Wizard's last screen will give the user the possibility of choosing how to present the results: a combination of charts, maps and reports.

2.1 Database module

As mentioned before, the conceptual data model was obtained by using structured analysis techniques [Yourdon 89], and contains the entities depicted in Figure 1.

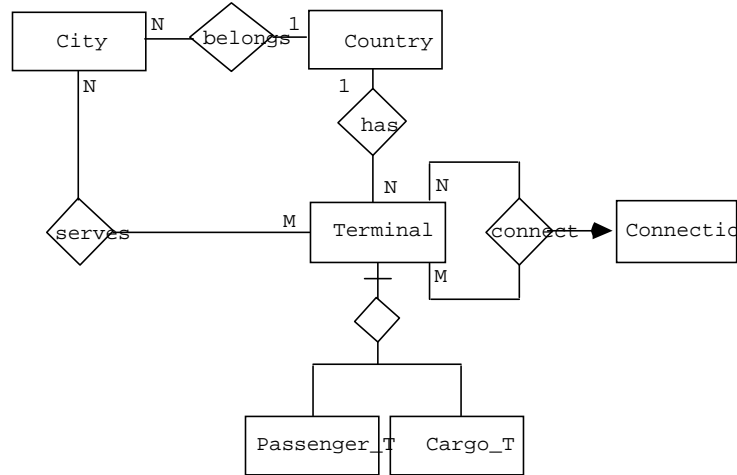


Figure 1: Entity relationship model for the intermodal terminals
 Each entity is described in terms of its attributes, both identifiers (preceded by @) and descriptors, as represented in Table 1.

Table 1: Entities data dictionary

Terminal = @coordinate + terminal_type + terminal_modes + terminal_name + address + services Cargo_T = @coordinate + DGHC + storage_capacity + cargo_types + specials + fridge + cranes + cargo_price Passenger_T = @coordinate + capacity + price + infrastructures Connection = @coordinate_origin + @coordinate_destiny + connection _mode Country = @country_code + country_name + GNP + labour_cost_hour + tax_level + extra + index_infrastructure + union + social_status + stability City = @city_code + city_name
--

The skeleton table we can derive from that entity relationship model is shown in Figure 2.

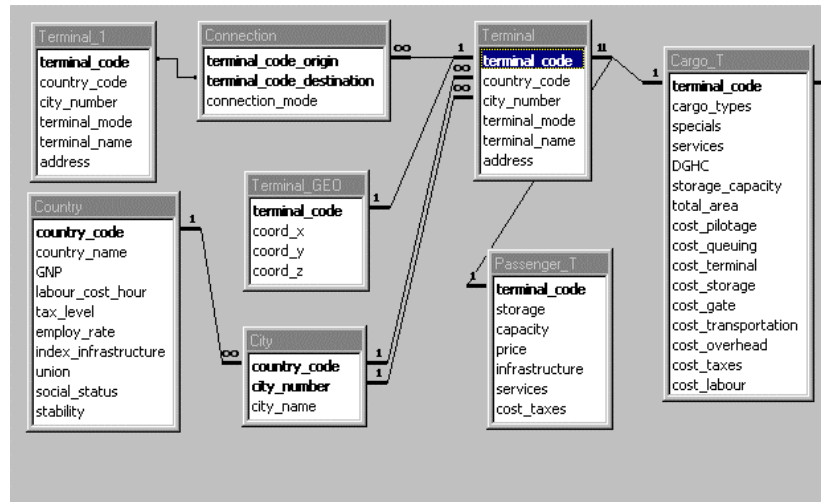


Figure 2: Tables implemented in the relational database

The database was filled in using the information (real values) available from the AND Mapping B.V. database, a company from Netherlands.

The database Wizard will allow the user to pick any relational database connected to the application and retrieve and modify data where and when appropriate. Access to data stored in the relational database is implemented through the ODBC (Open DataBase Connectivity) mechanism. This will allow to use other databases, from different vendors in a transparent mode, which makes the application more flexible and open. Moreover, with this strategy the application will be ready for a real client/server architecture with few adjustments.

2.2 Simulation module

The simulation model is the module of the decision support system which handles the selection and classification of terminals to recommend to the decision maker. This model includes two main tasks: (a) a pre-selection of terminals, according to user specific requisites and (b) a multicriteria analysis to rank those terminals, according to the user preferences (weights). The general description is shown in Figure 3.

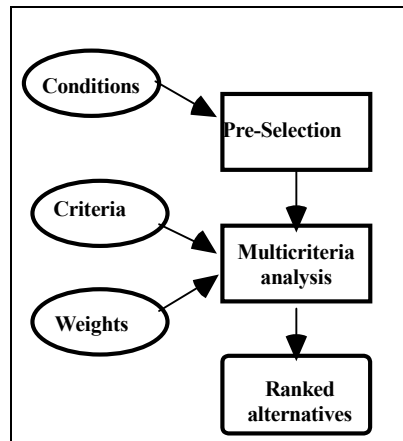


Figure 3: Main components of the simulation module

2.2.1 Pre-selection

The information needed to perform the pre-selection is taken both from the users and the databases. The users provide the conditions they need for the transportation of their goods and the system matches them with information on existing destination terminals, which fulfill those needs. These conditions are the restrictions of our DSS.

For example, we can choose conditions for the capacity (e.g. minimum value for lifting capacity of cranes) and also for prices (e.g. maximum value to spend in pilotage costs). Then, the pre-selection process matches these conditions with the data from the existing terminals and selects the set that fulfills the required conditions. The pre-selection process will be further detailed in the Interface Module section.

From this pre-selection process a set of possible alternatives is passed to the multicriteria analysis. In the multicriteria analysis, users select the criteria they want to be used for terminal selection and provide the weights for those criteria. With this information a multicriteria analysis, using fuzzy logic, is performed to rank the terminals.

2.2.2 Multicriteria analysis

We will start the development of the multicriteria model by defining the main features the multicriteria analysis should include. Secondly we will analyze the type of attributes defined and how to represent them in the

system. Thirdly we will define the most appropriate decision making algorithm to handle those attributes. Finally we will define the weighting procedure to allow the user to specify which are his/her preferences (relative importance) regarding the criteria and the attributes.

The main features of the multicriteria analysis model will be: (1) it accepts and manipulates both types of criteria, crisp and fuzzy; (2) it is interactive and user-friendly in the sense that all dialogue with the user is guided by scroll-bar menus and dialogue-boxes, from the 'construction' of specifications to the manipulation and selection of query-types; (3) it is a flexible system in terms of the handling of criteria and weights, such as new insertions and modifications of their respective values. (4) it incorporates simulation facilities, providing an efficient way for the user to change preferences-weights, enabling the tuning of the system and the verification of the variables sensitivity.

In order to achieve an optimal ranking of terminals, fuzzy set theory [Zadeh, 65] will be used because this problem involves many imprecise criteria such as stability, prices and infrastructure capabilities. Fuzzy set theory main objective is to solve problems in which descriptions of activities and observations are imprecise, vague and uncertain. It is a theory of graded concepts where everything is a matter of degree. For example the criteria stability can be expressed as "good", "average" and "bad". Formally, if \mathbf{X} is a collection of components denoted generically by \mathbf{x} then a fuzzy set \mathbf{A} in \mathbf{X} is a set of ordered pairs $\mathbf{A} = \{\mathbf{x}, \mu_{\mathbf{A}}(\mathbf{x}) \mid \mathbf{x} \in \mathbf{X}\}$, where $\mu_{\mathbf{A}}(\mathbf{x})$ is called the membership value or grade of membership of \mathbf{x} in \mathbf{A} . Another important aspect of decision making in a fuzzy environment is the reasoning process that takes place when a decision is made. When in the presence of imprecise concepts, this reasoning is usually denoted as approximate reasoning [Zadeh, 75].

The fuzzy multicriteria analysis model used in the simulation module is based in the MAF-DSS (Multiple-Attribute Fuzzy Decision Support System) developed by [Ribeiro, 93]. The main entities to be considered in the multicriteria analysis are alternatives, criteria, attributes and weights. Alternatives are the set of possible terminals determined by the pre-selection procedure. Criteria are the features used to classify the terminals, such as reliability, flexibility and cost. Attributes are the

criteria elements, they can be either crisp or fuzzy, as for example costs of pilotage, country social status and the stability of criteria reliability. Weights express the relative importance, attached by the user, for each criteria and their respective attributes. By default the weights are considered equivalent.

The multicriteria analysis (triggered by the run option on the menu *Simulation*) includes the following elements: (1) three evaluation criteria (cost, flexibility, reliability) with their respective attributes; (2) weights for the three evaluation criteria and also for the respective attributes; (3) Fuzzy attributes; (4) an aggregation algorithm for rating the terminals; (5) a ranking process for the selection of terminals (from best terminal to worst, of the set of possible ones). A summary of each element is described in the following subsections.

(1) Three evaluation criteria and respective attributes

There are three criteria in the DSS system and each criteria includes a set of sub-criteria, here called attributes. The criteria and respective attributes are the following:

Costs = overhead + pilotage cost + queing time + terminal cost + storage + gate cost + taxes + labour cost + GNP + transportation

Flexibility = storage + cranes + fridge + connection + TEN
accessibility + infrastructure

Reliability = unions + social status + stability

(2) Importance/Weights

The weights for the three criteria (cost, reliability and flexibility) and their respective attributes are defined as discrete fuzzy sets with the following labels:

[*irrelevant, low; important, very important, extremely important*]

The DSS presents a scale-bar to the user with the above labels, where each tick corresponds to the above membership labels. The user introduces his/her weights for the three upper level criteria (Costs, Flexibility, Reliability) and, when desired, for each of the detailed

attributes (there are three windows for the detailed attributes). By default the value is *irrelevant*.

(3) Fuzzy attributes

There are two types of attributes: crisp and fuzzy. Within the fuzzy attributes we can have discrete or continuous. The construction of the continuous attributes is as follows: (1) the *min* and the *max* values of each attribute is extracted from the database; (2) the type of function for that criteria (increasing or decreasing) is obtained from a database table. The *min* and *max* values correspond to the lowest value and highest value, contained in the database, for all terminals specific attributes. The type of function depends on the criteria, as for example: the attributes of cost criterion are always considered as decreasing (the lower the value the better). Note that if new terminals are included in the database, the new information will automatically change the *min* and the *max* from each attribute, if the values are higher or lower. Furthermore, new fuzzy sets are automatically re-calculated for each attribute when there new terminal inclusions.

The corresponding fuzzy sets are built with open-end triangular functions and the membership value $\mu(x)$ for each attribute, is calculated with the respective database values for that attribute, x , as follows:

Increasing linear function:

$$\mu(x) \begin{cases} 0 & x \leq \min \\ \frac{x - \min}{\max - \min} & \min \leq x \leq \max \\ 1 & x \geq \max \end{cases}$$

Decreasing linear function:

$$\mu(x) \begin{cases} 0 & x \geq \max \\ \frac{\max - x}{\max - \min} & \min \leq x \leq \max \\ 1 & x \leq \min \end{cases}$$

It should be noted that this construction is transparent to the users because the fuzzy attributes are built-in. All that is required from the users is the introduction of weights for the criteria and/or attributes.

The membership values $\mu(x)$ obtained for the attributes, for each terminal, is later used to calculate the final evaluation aggregation procedure for rating the terminals (using the respective weights for criteria evaluation).

(4) Aggregation procedure

The aggregation algorithm implemented in the simulation module is based in a fuzzy weighted average and uses a philosophy of “role model” or “ideal” terminal. This phase of the evaluation module corresponds to the *Rating* phase of the Fuzzy Multiple Attribute (FMA) approach [Zimmermann, 87] [Ribeiro, 96].

Formally, the aggregation formulas are:

$$Rating(C_j) = \sum_i W_i * Attr_i$$
$$FuzzyRating(Term_k) = \sum_j W_j * C_j$$

Where W_i is the importance of an attribute, $Attr_i$ is the membership value of the attribute, C_j corresponds to criteria (Cost, Flexibility or Reliability), W_j is the importance of criterion C_j and $Term_k$ is the terminal being evaluated. Furthermore, the weights are normalized and sum up 1.

The operators used for the fuzzy aggregation are the algebraic product and algebraic sum which belong to the set of *t-norms* and *t-conorms* [Klir, 88]. These type of operators satisfy the axioms of boundary, associativity, monotone non-decreasing and comutativity (similarity). Many other operators from the class of t-norms and even compensatory operators could have been used, but for reasons of simplicity we only used these ones.

Another interesting aspect of our DSS is the notion of distance from an “ideal” terminal. This measure shows how far away from the ideal any choice really is. The “ideal” is calculated using the sum of real values contained in the database for the attributes of a terminal and considers that all the attribute weights are 1 (*extremely-important*). Then we use the real values of attributes multiply them by the weights, given by the decision maker, to obtain the weighted average of the terminal evaluation.

Finally, we divide the two values to obtain the relation from a weighted terminal and its “ideal”. This is an original measure, proposed in this project, which accounts for the importances given by the user to each attribute and criteria, to obtain a final evaluation that shows how far away from the ideal each choice is. Hence, the “ideal” measure, per terminal, is obtained as follows:

$$Evaluation(Term_k) = \sum_j W_j * ValueAttribute_j / Ideal$$

This measure could also have been done using the membership values previously obtained. However, we choose to use the real values to highlight the relation between the sum of real values and the weighted sum.

(5) Hierarquization–Ranking

The final ordering of the terminals, which corresponds to the *Ranking* phase of the FMA approach [Zimmermann, 87] [Ribeiro, 96], is the descending order of the values obtained in the *Rating(Term)*. That is, the best terminal is the one with the highest rating value, the second best is the one with the second highest value and so forth.

The implemented system shows, in a summary report, both the *Evaluation* value and the *Rating(Term)* to help the decision making process. With the results obtained, the user has a rating and ranking of all possible terminals (the ones selected with the pre-selection) and if he is not satisfied he can always change some of the weights to perform a “what-if” analysis (simulation capability).

2.3 Interface module

We will describe the interface dialog using an example with a cargo terminal. The application (through a wizard) pops up the window depicted in Figure 4 which allows to specify the destination country of our goods. Optionally, we can also choose a destination city in the selected country. Still in this window we should also choose the type of terminal (passenger or cargo) and a set of alternative modes of transportation (railway, road, train, maritime, inland waterway, airway).

As mentioned in the introduction, the modes relate to the intermodal terminals.

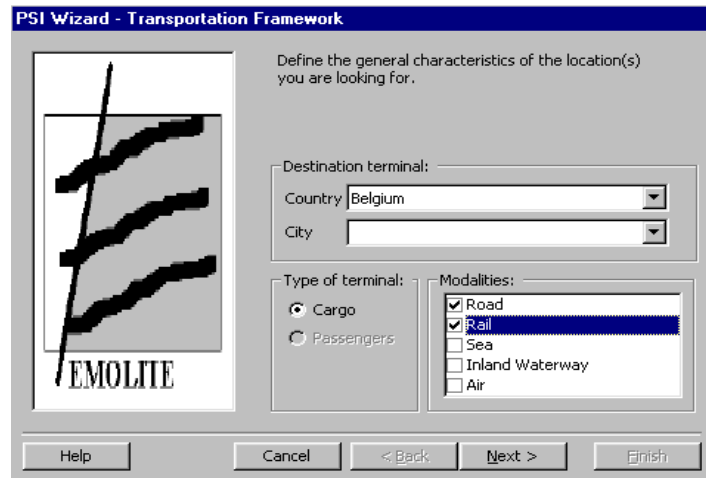


Figure 4: Transportation framework

If we choose to proceed clicking *Next*, the window depicted in Figure 5 appears:

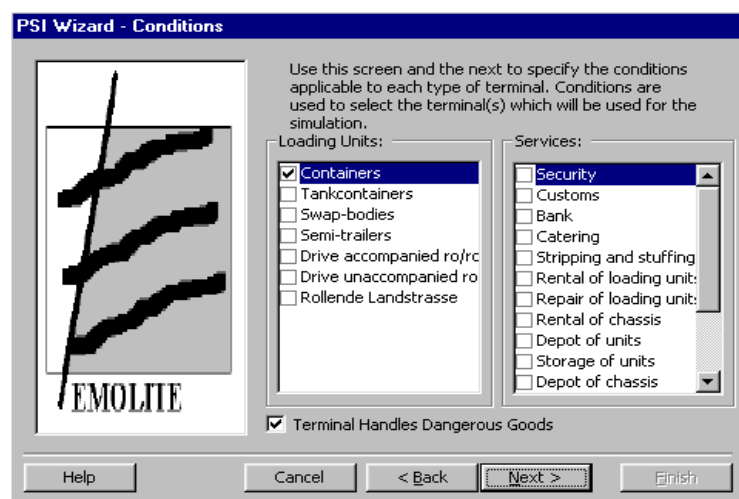


Figure 5: Terminal conditions

Figure 5 allows the user to specify the conditions applicable to each type of terminal. In other words, the user is able to narrow the set of terminals, evaluated for the intended purpose, through some conditional parameters. This step corresponds to the Pre-selection process (section 2.2.1).

The user may also select one or more types of loading units as well as services for the requested terminals. If the user selects more than one option, the possible terminals extracted from the database will have all the capabilities selected.

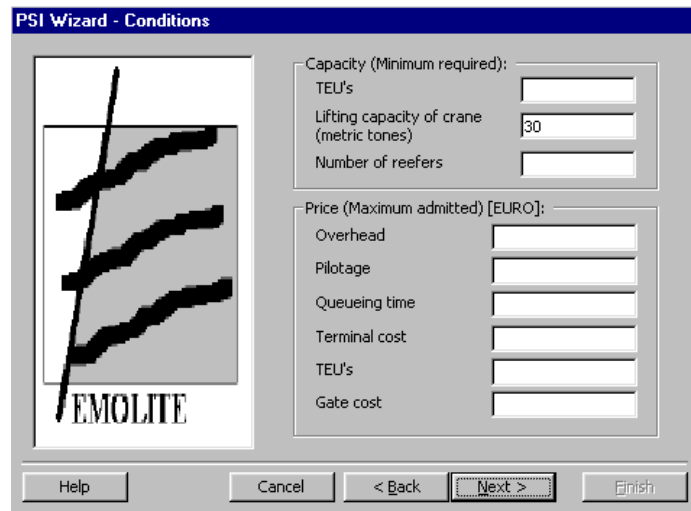


Figure 6: Terminal conditions (continuation)

If we proceed, the window displayed in Figure 6 will appear. This window allows the user to specify additional conditions applicable to each type of terminal. This step still corresponds to the "Pre-Selection" procedure. The user may enter minimum values for terminals' capacities as well as maximum admitted costs for various items. If the user enters more than one value, the set of possible terminals extracted from the database will obey to all the restrictions specified.

Clicking *Next* allows us to address the multicriteria analysis (see Figure 7):

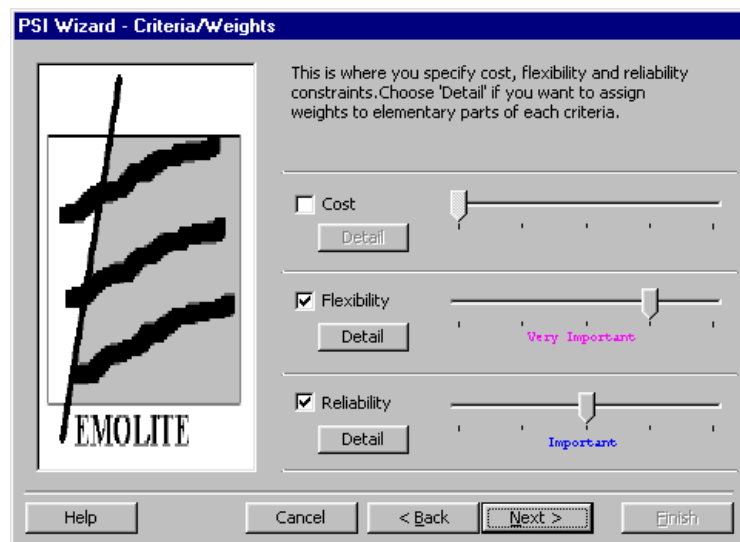


Figure 7: Multicriteria analysis

Figure 7 corresponds to the main interface of the multicriteria analysis (see section 2.2.2) for the specification of criteria weights that will apply to the set of possible terminals extracted from the pre-selection process.

The user may choose which criteria will be considered by (un)checking them. For each criteria checked the user defines the weight (relative importance) that he assigns to that criteria, using the scroll bar. For example, in Figure 7 the criterion flexibility has assigned and importance of *very-important*. The weights assigned at this (high) level will affect the criteria as a whole as explained in the Simulation Module section.

The next step is to assign weights to the attributes of each of the checked criteria. There are three detailed windows which correspond to the criteria cost, flexibility and stability. The process to give the weights for the attributes is identical to the one of giving weights to criteria. Note that when a criterion is checked it is mandatory to assign at least one weight to its elementary criteria (i.e. the attributes). For reasons of space we only show one example (see Figure 8) which depicts the detailed costs for flexibility.

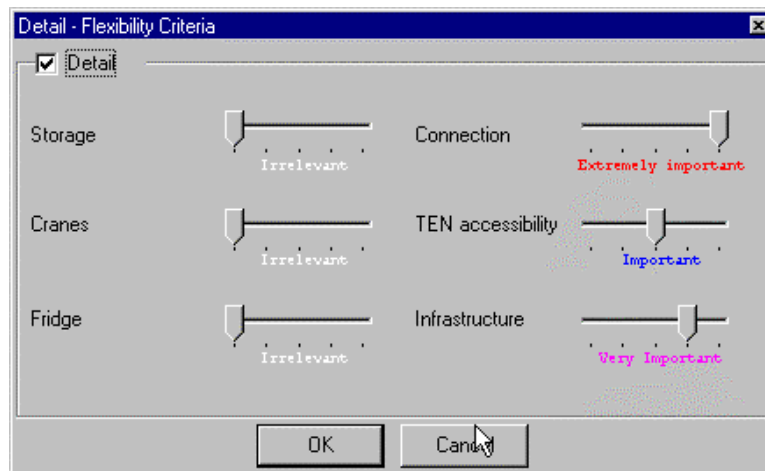


Figure 8: Definition of detailed attributes for flexibility criteria

When the assignment of weights for the detailed criteria is finished a final window is presented to the user to allow choosing the preferred presentation style: Full Report, Summary Report, Graph, Map. This final dialog window is not shown here for reasons of space, but the resulting windows are depicted in Figure 9 and 10.

Summary Report				
Number of locations found: 33				
Rank	Terminal	Evaluation	Fuzzy	Final
1	Antwerpen-Noord Natie-Delwaidedok	29,920	0,124	1,000
2	Antwerpen-ACT-6th Harbour Dock	29,339	0,122	0,981
3	Antwerpen-ACT-7th Harbour Dock	28,762	0,119	0,961
4	Zeebrugge-Ocean Containerterminal Hessena	28,680	0,119	0,959
5	Antwerpen-Noord Natie-Noordzee Terminal	28,674	0,119	0,958
6	Antwerpen-Seaport-Hansadok	28,301	0,117	0,946
7	Antwerpen-Hessenatie-Scheldeterminal	28,076	0,116	0,938
8	Renory-Container Terminal	27,939	0,116	0,934
9	Antwerpen-Hessenatie-Delwaidedok	27,881	0,116	0,932
10	Antwerpen-Seaport-Delwaidedok	27,881	0,116	0,932
11	Antwerpen-Allied Stevedores-Terminal Delwai	27,881	0,116	0,932
12	Athus	27,834	0,115	0,930
13	Antwerpen-Interferry	27,782	0,115	0,929
14	Antwerpen-Hessenatie-Churchilldok	27,589	0,114	0,922
15	Antwerpen-Seaport-Vrasenedok	27,545	0,114	0,921
16	Bressoux (Liège)	27,543	0,114	0,921
17	Antwerpen-Seaport-Churchilldok	27,377	0,114	0,915
18	Antwerpen-Westerlund	27,340	0,113	0,914
19	Mouscron-DPMLI	27,282	0,113	0,912
20	Zeebrugge-Flanders Container Terminal	27,274	0,113	0,912
21	Zeebrugge-Sea-Ro Terminal	27,251	0,113	0,911
22	Antwerpen-Mexico Natie-Berths 8-11	27,251	0,113	0,911
23	Antwerpen-Cirkeldyk	27,198	0,113	0,909
24	Gent-Farman	27,198	0,113	0,909

Figure 9: Summary report

After running the simulation the results are depicted in the summary report as shown in Figure 9. These results show an example of the ranking of the possible set of terminals, after being evaluated with the fuzzy multiple attribute simulation model. They depict the global evaluation (*Evaluation*), the respective aggregated membership value (*Fuzzy*) and the normalized fuzzy membership value (*Final*). The results obtained refer to terminals of the selected country, Belgium. It should be pointed that the global evaluation value is the relation between the ideal value and the value obtained for the terminal, as described in section 2.2.2.

It is also possible to double-click on every terminal presented in Figure 9. If this happens, the system will open a window showing detailed information about the terminal we just selected in the summary report.

As mentioned, graphs can also be selected to better appreciate the results of the simulation. This type of window is updated every time a simulation runs. For readability reasons, only ten terminals are presented at one time. The graph in Figure 10 shows the global evaluation and the flexibility criteria evaluation for the first ten terminals ranked:

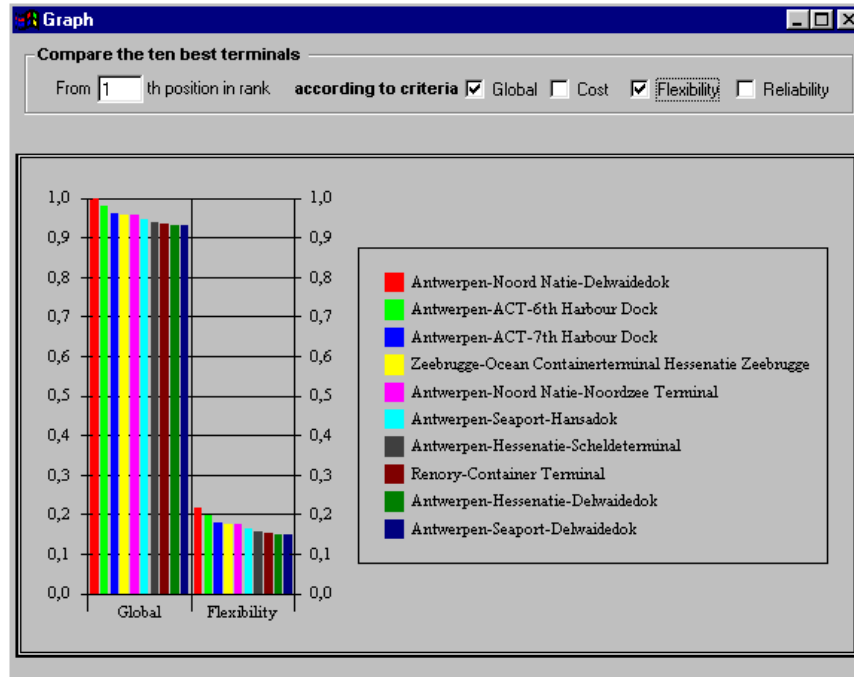


Figure 10: Graphical representation of 10-top terminals ranked

In addition, the results obtained from any simulation can be saved and used in the future.

3 Conclusions

Our work joined efforts from several different experts (e.g. transports and logistics, computing science) to produce an evaluation model to identify the optimal intermodal destination terminals in Europe. The objective was to provide a ranked list of possible destination terminals to a decision maker that wishes to send his goods to an European country.

The decision support system built has been developed following a rapid prototyping approach. We started building the user interfaces during the requirements analysis phase. This helped us understanding the requirements and having a tool to communicate within our team.

The development techniques used come from classical structured techniques, such as structured analysis, to artificial intelligence concepts, such as fuzzy set theory.

Our decision support system is a classical one, composed of three modules: database, simulation and interface. The main advantages of our

Draft of paper in: Applied Decision Support with Soft Computing.
Editors: X. Yu, J. Kacprzyk, C. Carlsson
Studies in Fuzziness and Soft Computing Series, Springer-Verlag (2003)

system are: it is an interactive and user-friendly system; it is a flexible system for handling intermodal terminal features (conditions, criteria and weights); it incorporates a simulation facility, where the users can compare what are the results of changes in their criteria weights in the ranking of terminals; it includes various types of result forms to support the decision maker's decision process.

ACKNOWLEDGMENTS

This work has been realized under the support of the European Commission, project EMOLITE, contract nr. ST-96-SC.1018.

REFERENCES

- Klir, G. J. and T. A. Folger (1988). *Fuzzy Sets, Uncertainty, and Information*, Prentice-Hall International.
- Ribeiro R. A. (1993). Application of Support Logic Theory to Fuzzy Multiple Attribute Decision Problems. PhD Thesis, University of Bristol, UK.
- Ribeiro R. A. (1996). Fuzzy Multiple Attribute Decision Making: A Review and New Preference Elicitation Techniques. *Fuzzy Sets and Systems* Vol. 78, pp. 155-181.
- Turban, E. (1996). *Decision Support and Expert Systems*, Macmillan Publishing Company.
- Yourdon, E. (1989). *Modern Structured Analysis*, Prentice-Hall.
- Zadeh, L. A. (1965). Fuzzy Sets, *Information and Control*. Vol. 8, pp. 338-353.
- Zadeh, L. A. (1975). Fuzzy Logic and Approximate Reasoning. *Syntheses*, Vol. 30, pp. 407-428.
- Zimmermann, H.-J. (1987). *Fuzzy Sets, Decision Making, and Expert Systems*. Kluwer Academic Publishers.